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Space Administration
NASA
life in the
extremes
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Extremophiles are organisms that live in places on Earth that humans would consider "extreme." Hot spring pools, glaciers, the bottom of the ocean—these are all environments that we might have a hard time living in, but the organisms featured on these cards feel right at home there. Astrobiologists are interested in extremophiles here on Earth because they study similar environments on other planets and moons that may have extremophiles, too.

Ideas for using these Life in the Extremes cards:

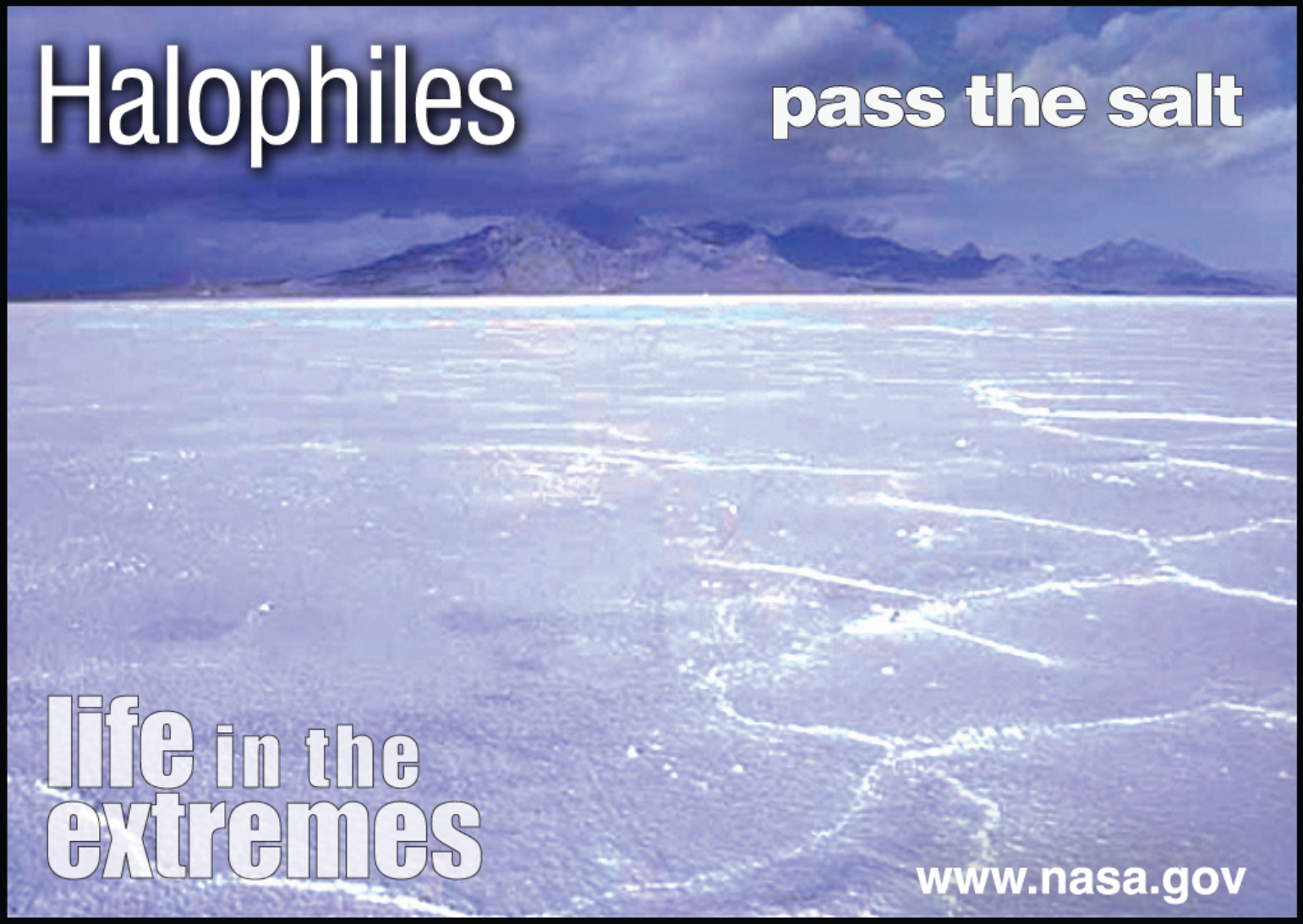
1) What is life? Make a list of the features that living creatures share. Are there non-living things that fit your definition of life (icicles, clouds, fire)?

2) What does life need to survive? If you were planning a trip to Mars, what would you absolutely need to take along to survive? Do other life forms need similar things? What are the most basic needs we all share?

3) Learn more about Mars, Europa (a moon of Jupiter), and Titan (a moon of Saturn). If there is life beyond Earth, what kind of extremophiles would you expect to find on each planet or moon, and why?

4) If you were looking for life elsewhere in our Solar System, how would you search? What tools would you need? What would you study here on Earth to make you better prepared to look for life somewhere else?

For more information:
http://astrobiology.nasa.gov/


Halophiles
pass the salt
life in the extremes
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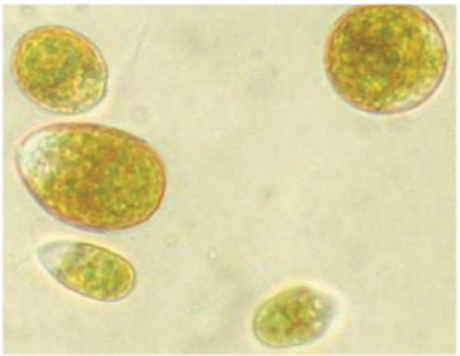

Dunaliella salina is a kind of algae that lives in salt ponds. To protect itself from sunlight, *Dunaliella* concentrates beta-carotene in its cell wall, giving it an orange or pinkish color.

EXTREME ABILITY Halophiles coat themselves with a special protein layer which allows only certain levels of salt into the cell. This layer also helps to seal in water with the right level of saltiness.

EXTREME ENVIRONMENTS Ocean water is about 3.5% salt. The water in salt ponds and other halophilic environments is typically 5 to 10 times saltier than normal ocean water. This means that a gallon of water from some salt ponds contains as much as 2.5 pounds of dissolved salt!

EXTREME EXAMPLES These salt lovers live in places like the Great Salt Lake in Utah, Owens Lake in California, and the Dead Sea between Israel and Jordan. Halophilic bacteria also occasionally grow on saltine crackers.

Photo Credit: Bonneville Salt Flats - Utah Bureau of Land Management (front); *Dunaliella salina* - P. Lamers, Bioprocess Engineering Group, Wageningen University, The Netherlands (back). For more information visit http://astrobiology.nasa.gov/


Psychrophiles
deep freeze
life in the extremes
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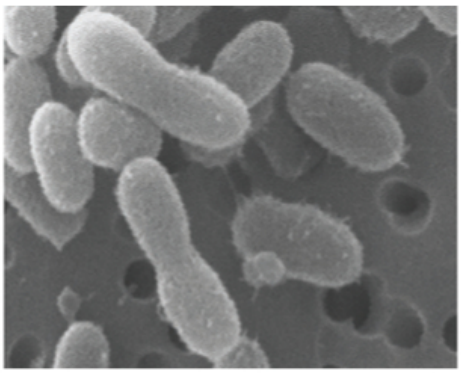

Chryseobacterium greenlandensis is an ultra-small bacterium that has survived for up to 120,000 years within the ice of a Greenland glacier, nearly two miles down.

EXTREME ABILITY Most true psychrophiles require temperatures below -4 °F to survive. To protect their DNA, some species produce special proteins that act as anti-freezing agents. Other species have evolved cell layers that resist stiffening in the cold.

EXTREME ENVIRONMENTS Psychrophiles can be found in Arctic soils, deep ocean water, glaciers, snowfields, sea ice, and tundra. Scientists are trying to determine if Jupiter's icy moon Europa is home to cold-loving microbes.

EXTREME EXAMPLES These microbes can cause widespread crop disease. *Leifsonia* sp., for example, are especially destructive bacteria that have caused enormous amounts of damage to sugarcane crops.

Photo Credit: Perito Moreno Glacier, Argentina - Luca Galuzzi (front); *Chryseobacterium greenlandensis* - Penn State (back). For more information visit http://astrobiology.nasa.gov/


Acidophiles
sourpusses
life in the
extremes
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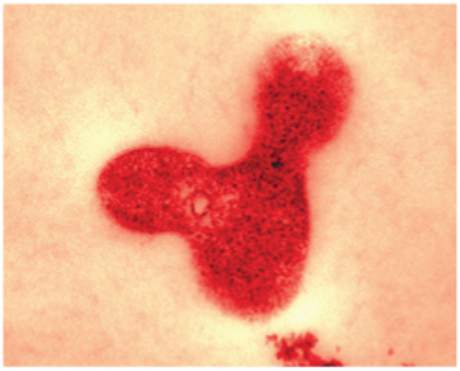

Ferroplasma acidiphilum extracts energy from iron–it "eats" the metal and leaves rust behind.

EXTREME ABILITY Acids, such as the citric acid in lemons, taste sour. Even the word acid comes from the Latin word *acidus* meaning "sour." Acidophiles survive in very acidic environments where pH rarely rises above 3. When other organisms are exposed to such acidic conditions their DNA is damaged beyond repair.

EXTREME ENVIRONMENTS These organisms are most commonly found in mine drainages, waste treatment plants, and sulfuric acid hot springs. Scientists speculate that acidophiles could live in the toxic clouds of Venus' atmosphere.

EXTREME EXAMPLES Acidophiles play a complex role in acid mine drainage and some are used in coal mining to recover metallic minerals and to reduce sulfur levels.

Photo Credit: Algae flow patterns at Yellowstone National Park - J. Schmidt, NPS (front); *Ferroplasma acidiphilum* - Helmholtz Centre for Infection Research (back). For more information visit http://astrobiology.nasa.gov/


Radioresistant
Microbes
life in the
extremes
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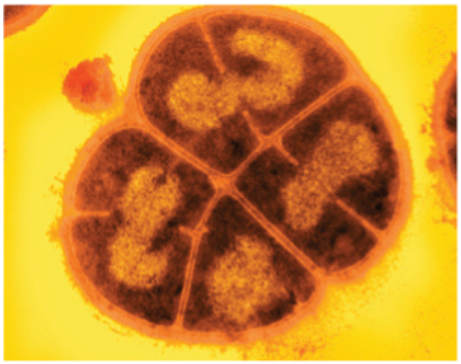


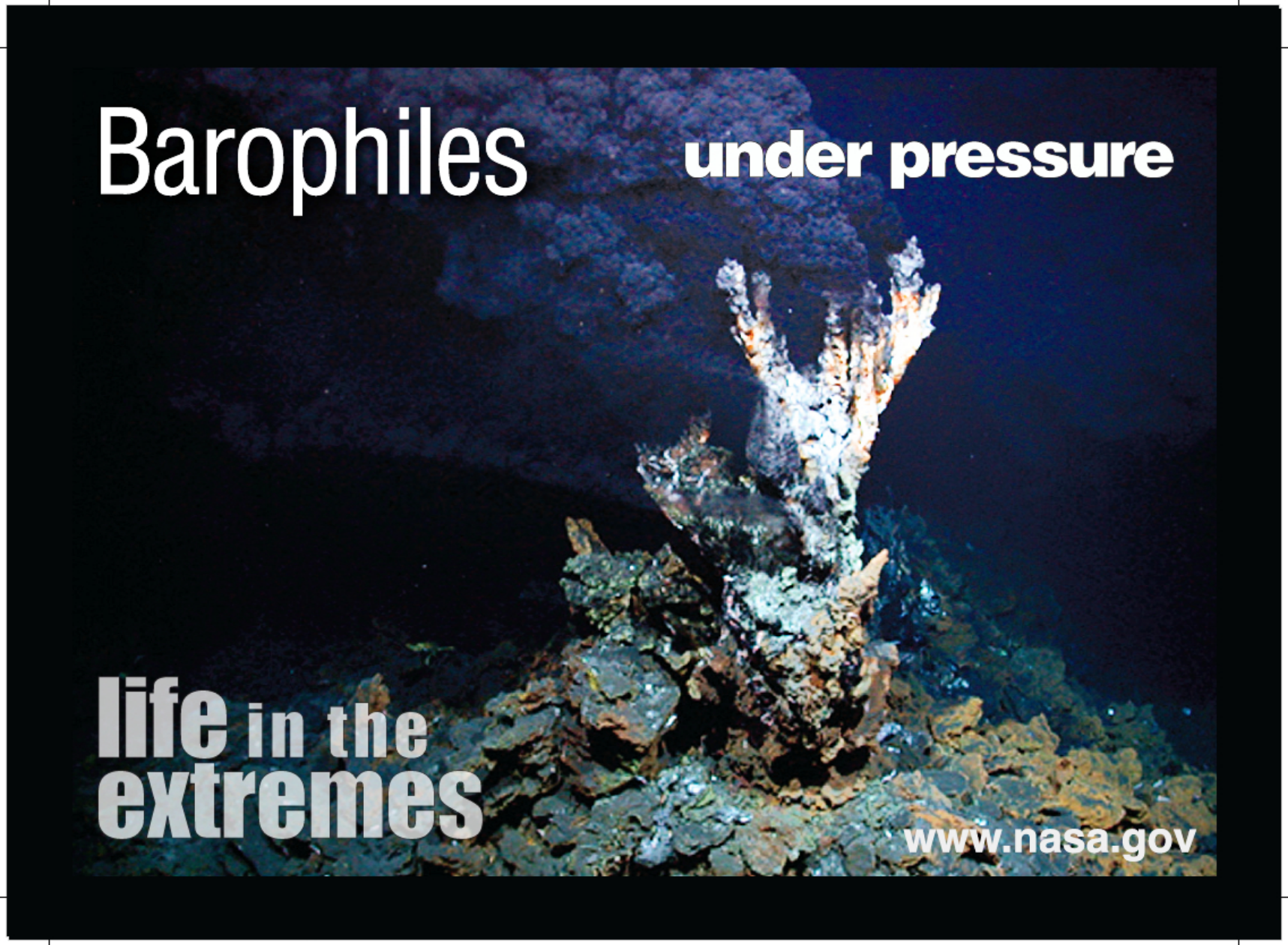
The bacterium *Deinococcus radiodurans*, shown here as a group of four cells, is resistant to drying, ultraviolet light, and immense doses of gamma rays.

EXTREME ABILITY These extremophiles consistently survive doses of radiation that are 500 times greater than the lethal dose for humans.

EXTREME ENVIRONMENTS Radioresistant fungi were found growing in the remains of the Chernobyl nuclear reactor, which was destroyed by a steam explosion in 1986. Scientists determined that the extremophile fungi were using energy from radioactivity to produce food for themselves.

EXTREME EXAMPLES *Deinococcus radiodurans* is listed in the Guinness Book of World Records as "the world's toughest bacterium." In addition to being resistant to radiation, these bacteria can also survive severe droughts, extreme cold, and strong acids.

Photo Credit: U.S. Nuclear Regulatory Commission (front); *Deinococcus radiodurans* - Michael J. Daly, Uniformed Services University (back). For more information visit http://astrobiology.nasa.gov/


Barophiles
under pressure
life in the extremes
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Space Administration

Barophiles can live in highly pressurized places such as the bottom of the ocean floor near hot vents like those seen on the front of this card.

EXTREME ABILITY Whereas most living creatures cannot survive the extreme forces that exist below the Earth's surface and on the sea floor, these microbes thrive under high pressure. They evolved a waxy cell layer which protects against crushing pressures and frigid temperatures.

EXTREME ENVIRONMENTS These extremophiles can be found almost everywhere on Earth, but most barophiles are found on the ocean floor where pressures are 400 times greater than on Earth's surface.

EXTREME EXAMPLES The barophile *Halomonas salaria* requires a pressure 1000 times grater than Earth's surface atmosphere just to stay alive!

Photo Credit: Black smoker at the bottom of the sea floor - MARUM, Bremen University, Germany (front); Barophile - Dr. Chiaki Kato, Japan Agency for Marine-Earth Science and Technology (back). For more information visit http://astrobiology.nasa.gov/


Alkaliphiles
just the basics
life in the extremes
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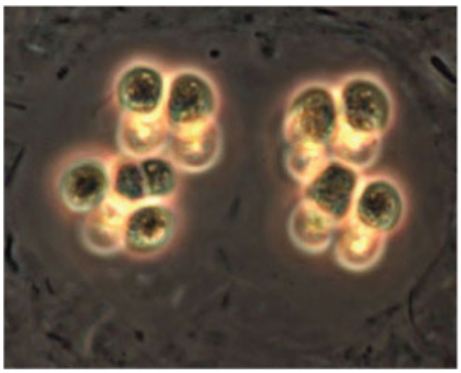

Colonies of blue-green bacteria called *Microcystis* flourish in alkaline environments like Mono Lake, California seen on the front of this card.

EXTREME ABILITY Alkaliphiles thrive in substances that are capable of neutralizing strong acids. These alkaline environments typically have pH values ranging from 9 to 11. To survive such harsh conditions, these organisms have evolved unique enzymes, specialized cytoplasm, and efficient cell membranes to protect their cells from damage.

EXTREME ENVIRONMENTS These microbes inhabit such places as soda lakes, caves, alkaline hot springs, deserts, and waste dumps from mines.

EXTREME EXAMPLES Alkaliphiles are used in making paper and recovering spilled oil. They are also common ingredients in dishwashing detergent and laundry soap.

Photo Credit: Mono Lake, California is 80 times more alkaline than the ocean - Mila Zinkova (front); *Microcystis* - David Patterson and micro*scope (back). For more information visit http://astrobiology.nasa.gov/


Xerophiles
hung out to dry
life in the extremes
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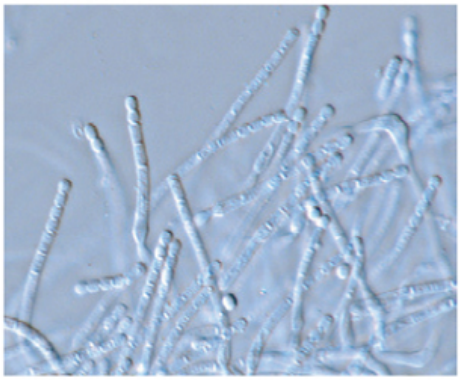


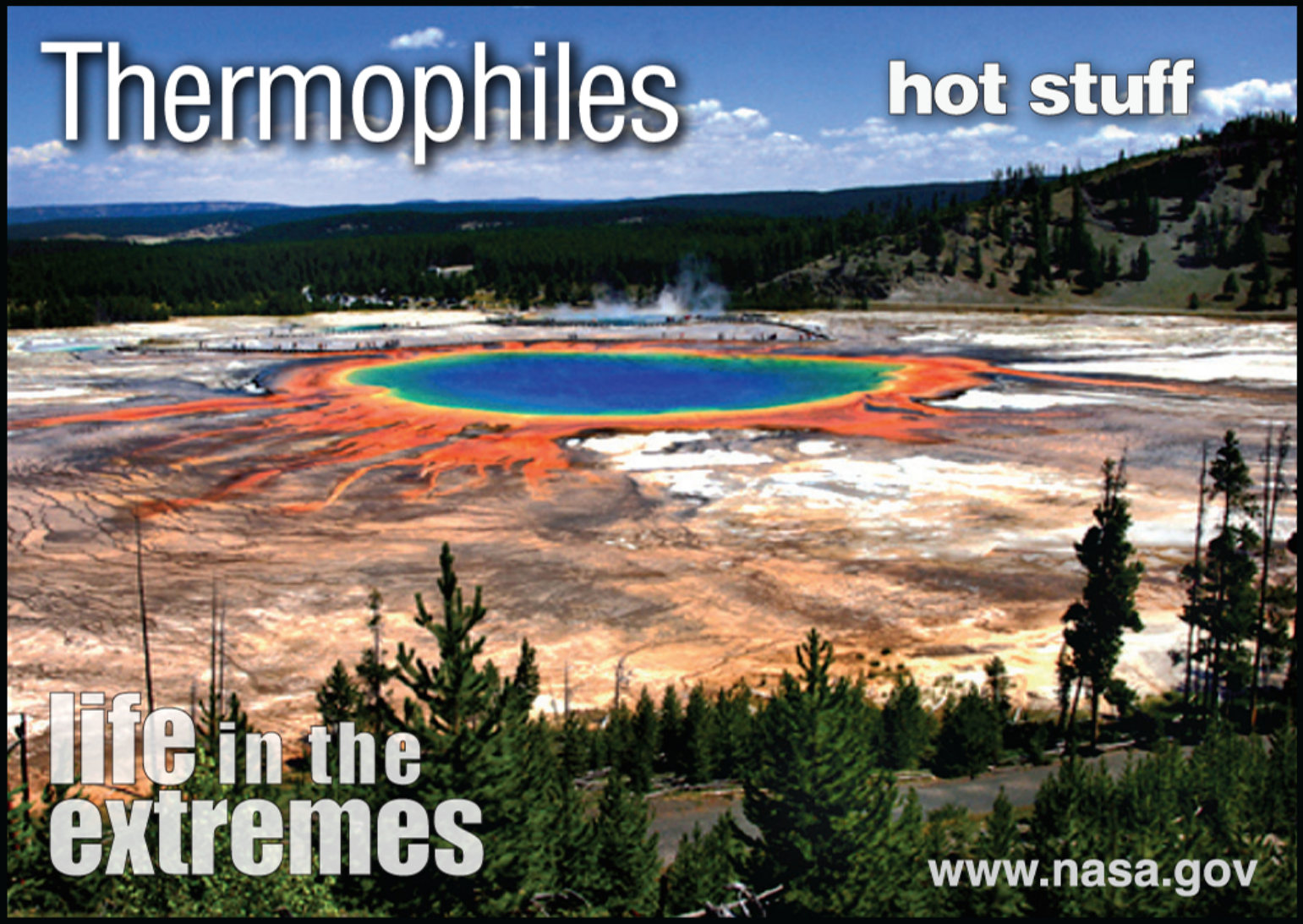
Wallemia sebi is a mold that grows in settings with little water such as dried fruits, salted meats, and salterns (the evaporitic beds where sea salt is produced).

EXTREME ABILITY Xerophiles can grow and reproduce in conditions with little water available. This group of organisms is named from the Greek words *xeros* meaning "dry," and *philos* meaning "loving."

EXTREME ENVIRONMENTS Some xerophiles live in pretty normal places like old food (nuts and jam especially), but others thrive in harsher conditions. Xerophiles can live in deserts and salt beds where most living creatures would dehydrate quickly!

EXTREME EXAMPLES Many mold and yeast species are xerophilic. Mold growth on bread is an example of food spoilage by xerophilic organisms. Xerophiles commonly live on food that has been dried for storage outside of the refrigerator.

Photo Credit: Atacama Desert, Chile is the world's driest desert - NASA (front); *Wallemia sebi* - Kathie Hodge, Cornell (back). For more information visit http://astrobiology.nasa.gov/


Thermophiles
hot stuff
life in the extremes
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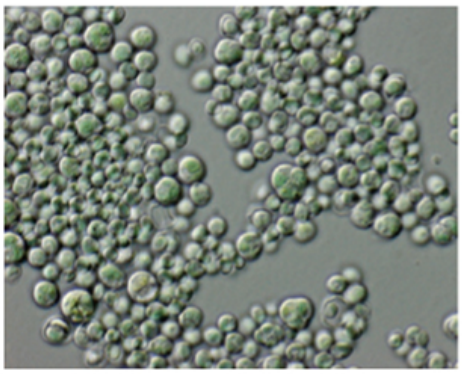

Cyanidium, a type of algae, loves the hot springs at Yellowstone National Park. This thermophile can make the pools it lives in green.

EXTREME ABILITY These microbes have developed special proteins that allow them to tolerate a broad range of temperatures—some even require temperatures around 140 °F to exist at all.

EXTREME ENVIRONMENTS Thermophiles can be found all over the world in places like hot springs, crater lakes, peat bogs, and superheated hydrothermal vents on the sea floor.

EXTREME EXAMPLES *Thermus aquaticus,* a bacterium found in a Yellowstone hot spring, produces an enzyme that allows for quick DNA replication. Scientists call it *Taq* Polymerase, and its use has revolutionized biotechnology all over the world.

Photo Credit: Grand Prismatic Spring at Yellowstone National Park - Mila Zinkova (front); *Cyanidium* - David Patterson and micro*scope (back). For more information visit http://astrobiology.nasa.gov/


Endoliths
kings of rock
life in the
extremes
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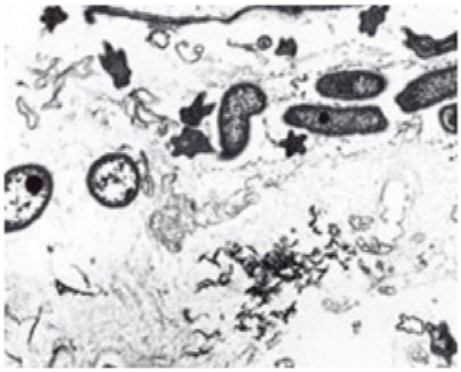


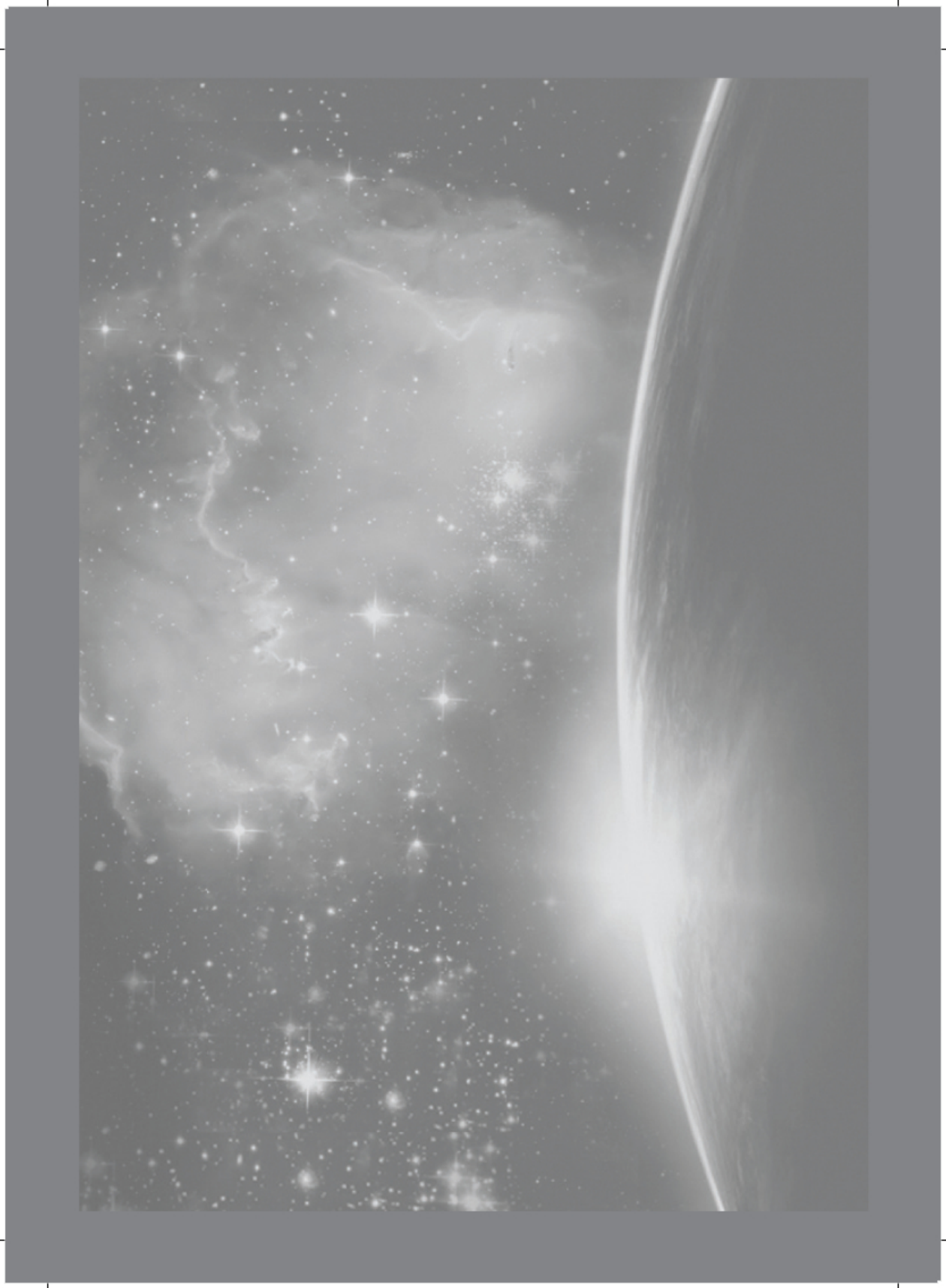
This community of microbes was collected more than one mile deep in a South African platinum mine. It contains star-shaped bacteria that had never been seen before.

EXTREME ABILITY Endoliths make their homes inside of rocks. They can live for hundreds of years by feeding on the traces of iron, phosphorus, and sulfur in their host rocks.

EXTREME ENVIRONMENTS Rocks in deserts and on mountain slopes often contain endoliths. Some endoliths have been found within the Earth's crust at a depth of nearly two miles.

EXTREME EXAMPLES Many scientists think that endoliths are a good candidate for the type of life most likely to be discovered living on Mars now or in the past, since harsh conditions may have driven them underground.

Photo Credit: Endoliths in a rock from the Transantarctic Mountains - Kevin Hand (front); Microbial biofilm - G. Wanger, J. Craig Venter Institute and G. Southam, The University of Western Ontario (back). For more information visit http://astrobiology.nasa.gov/

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